Amendments to the Written Description of the Specification

Applicant presents replacement paragraphs below indicating the changes with insertions indicated by underlining and deletions indicated by strikeouts and/or double bracketing.

On page 1, after the title insert: --Background Of The Invention--;

On page 1, after "Background of the Invention" but before the first paragraph insert --Field of the Invention--;

Please amend all paragraphs on page 1 as shown below:

--The present invention relates to methods and apparatus for ~~synchronisation~~ synchronization of a received signal, and in particular to methods and apparatus for use in telecommunications networks. The present invention also relates computer program products for ~~synchronisation~~ synchronization to a received signal in which data is sent in frames and training sequences are provided for ~~synchronisation~~ synchronization. The present invention particularly relates to telecommunications networks in which data is sent in frames and training sequences are provided for ~~synchronisation~~ synchronization, e. g. especially to OFDM and COFDM telecommunications systems.

There are many forms of known telecommunications systems including wireless based and wireline systems. Such systems may be used to transfer voice or data systems across a variety of channels, e. g. satellite, optical fibre, coaxial cable, cellular wireless, point-to-point microwave systems. In general there is a transmitter for transmitting a signal and a receiver for receiving the signal as part of the system. To improve reception, the transmitted signal may be coded in a variety of ways. A digital signal received at a receiver must be ~~synchronised~~ synchronized in some way in order to extract any message conveyed in the signal. There are various ways in which ~~synchronisation~~ synchronization can be achieved. For instance, a known symbol sequence (e. g. a training symbol sequence) may be correlated with a received signal known to contain the same sequence. This may be called cross-correlation. Training sequences are widely used for ~~synchronisation~~ synchronization. Alternatively, if the transmitted signal

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

includes a repeated or cyclic sequence, such as a cyclic symbol prefix as can occur in OFDM (Orthogonal Frequency Division Multiplex) systems, the cyclic sequence may be autocorrelated with the same prefix received at a different time.

Such ~~synchronisation~~ synchronization methods are known, for instance, from"Robust Frequency and Timing Synchronization for OFDM", Scmidl and Fox, IEEE Trans. On Communications, vol. 45, no. 12, December, 1997 and "On Synchronization in OFDM Systems using the cyclic prefix", Jan-Jaap van de Beek, Magnus Sandfell, Per Ola Börjesson, Proc. of the RVK 96, pages 663-667, Lulea, Sweden, June 1996.--

Please amend page 2, lines 5-33 as shown below:

--~~Synchronisation~~ synchronization can become more difficult when there is a clock offset between the transmitter clock and the receiver clock. The channel across or through which the data is transmitted may distort received signals which may make ~~synchronisation~~ synchronization more difficult. In radio systems there may be multiple paths between the transmitter and receiver which result in receipt of multiple signals delayed with respect to each other depending upon the length of the path. In the presence of channels having long impulse response times (that is, those in which the impulse response time is comparable to the length of the training sequence or the cyclic sequence), the accuracy of ~~synchronisation~~ synchronization drops. Intersymbol Interference(ISI) becomes worse when the impulse response time is long and this can have a negative effect upon ~~synchronisation~~ synchronization and, as a result, on the operation of a receiver. A further problem, especially with OFDM systems is carrier frequency offset. OFDM systems are more sensitive to frequency offset and phase noise than single carrier systems. In an OFDM system the subcarriers are perfectly orthogonal only if the transmitter and receiver use exactly the same frequencies. Any frequency offset results in Intercarrier Interference. Hence, frequency offset must be ~~minimised~~ minimized. A related problem is phase noise. A practical oscillator does not produce a carrier at exactly one frequency, but rather a carrier that is phase modulated by random phase jitter. As a result the received frequency is never constant. The received signal may also contain general noise, e. g. white Gaussian noise.

The first part of a typical OFDM frame comprises a preamble, for example aHIPERLAN/2 preamble consists of a short (STS) and a long training sequence (LTS). The STS contains repetitions of a training symbol with duration of 800ns on 12subcarriers. Each of the symbols is a quarter of the duration of the part of a normal data symbol ~~analysed~~ analyzed by the Fast Fourier Transform. Each data symbol of an OFDM signal has a cyclic prefix, i.e., the first To seconds part of each OFDM symbol is identical to the last part. The preamble also includes a long training sequence which two data symbol and a cyclic prefix. The STS may be used for coarse frequency estimation whereas the LTS may be used for precise frequency estimation. The STS may also be used for symbol timing estimation by cross-correlation.--

Please amend lines 1-7 as shown below:

--An object of the present invention is to provide a method and apparatus for improved ~~synchronisation~~ synchronization of a received signal.

A further object of the present invention is to provide a method and a system which allows robust ~~synchronisation~~ synchronization even under extreme conditions.

Still a further object of the present invention is to provide a method and a system which allows ~~synchronisation~~ synchronization with lower risk of perturbation caused by intersymbol interference.--

Please amend lines 24-32 as shown below:

--The frequency offset estimation unit may comprise means for determining a phase shift in the autocorrelation signal of the received signal. The receiver may also comprise means to detect a characteristic curve indicative of a known training sequence in the phase of the autocorrelation signal. The receiver may comprise means to detect a characteristic curve indicative of a known training sequence in the amplitude of the autocorrelation signal. The characteristic curve may include peaks and/or troughs. To avoid spurious ~~synchronisations~~ synchronizations threshold values may also be used to make sure that only very significant peaks and troughs are detected while not being misled by the exact form of the peak or the trough. The threshold values may be set dynamically.--

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

Please amend lines 4-18 on page 4 as shown below:

--The receiver may have means for determining an autocorrelation signal from a further known sequence of the received signal. For example, the receiver may have means for determining a phase shift in the autocorrelation signal from a further known sequence of the received signal. The time reference determining unit may comprise means to determine a characteristic curve indicative of a known training sequence or a further known sequence in the amplitude of the autocorrelation signal. The time reference determining unit may comprise means to determine a characteristic curve indicative of a known training sequence in the phase of the autocorrelation signal. The time reference determining unit may comprise means to determine a characteristic curve indicative of a known training sequence in the amplitude of the cross-correlation of the compensated received sequence with the known training sequence. The characteristic curve may include peaks and/or troughs. To avoid spurious ~~synchronisations~~ synchronizations threshold values may also be used to make sure that only very significant peaks and troughs are detected while not being misled by the exact form of the peak or the trough. The threshold values may be set dynamically.--

Please amend lines 3-10 as shown below:

--The present invention also provides a receiver which receives a signal comprising a first and second known training sequence and uses autocorrelation of the first or the second known sequence for CFO estimation, autocorrelation of the first known sequence for a first timing and cross-correlation of the second known sequence for a second timing. Either the first or the second timing may be selected as the timing of the received signal. The first known sequence may be an STS sequence of a preamble and second known sequence may be an LTS of a preamble. The use of different known sequences increase the accuracy of the ~~synchronisation~~ synchronization.--

Please amend the paragraphs beginning on page 6, line 8 of through page 7, line 1 of as shown below:

--The present invention may provide a receiver for receiving a signal comprising a carrier modulated with a known training sequence comprising:

an autocorrelation unit for generating a phase and an amplitude autocorrelation signal by autocorrelation of a known sequence in the received signal, a time reference determining unit for obtaining a timing reference for the received signal, the time reference determining unit comprising means to detect ~~synchronisation~~ synchronization using both the phase and amplitude signals.

The present invention may provide a method for obtaining a timing reference form a received signal comprising a carrier modulated with a known training sequence comprising:

generating a phase and an amplitude autocorrelation signal by autocorrelation of a known sequence in the received signal, and obtaining a timing reference for the received signal by detecting ~~synchronisation~~ synchronization using both the phase and the amplitude signals.

The present invention may also provide a receiver for receiving a signal comprising a carrier modulated with a known training sequence comprising: an autocorrelation unit for generating an autocorrelation signal by autocorrelation of a known sequence in the received signal, a time reference determining unit for obtaining a timing reference for the received signal, the time reference determining unit comprising means to detect ~~synchronisation~~ synchronization by detecting at least two ~~synchronisation~~ synchronization conditions in the autocorrelation signal.

The present invention may also provide a method for obtaining a timing reference form a received signal comprising a carrier modulated with a known training sequence comprising: generating an autocorrelation signal by autocorrelation of a known sequence in the received signal, and obtaining a timing reference for the received signal by detecting ~~synchronisation~~ synchronization using at least two ~~synchronisation~~ synchronization conditions in the autocorrelation signal.--

Please amend lines 14-17 on page 7 as shown below:

--Fig. 3 is a detail of a timing and frequency ~~synchronisation~~ synchronization unit in accordance with an embodiment of the present invention.

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

Fig. 4 is a representation of an autocorrelation unit and frequency offset unit which may be used with the timing and frequency ~~synchronisation~~ synchronization unit of Fig. 3.--

Please amend lines 27-28 on page 7 as shown below:

--Fig. 6 shows a cross-correlator in the form of a matched filter for use in the timing and frequency ~~synchronisation~~ synchronization unit of Fig. 3.--

Please amend the paragraph beginning on page 7, line 33 through page 8, line 1 as shown below:

--Fig. 9a is a schematic block diagram of a ~~synchronisation~~ synchronization machine in accordance with an embodiment of the present invention.--

Please amend lines 6-17 on page 8 as shown below:

--Fig. 10a shows how a sliding correlation can be performed. Figs. 10b and 10c show forms of sliding correlations with varying correlation distance D which may be used with the present invention.

Figs.11a and 11b show schematic representations of the mechanism of autocorrelation and cross correlation which can be used with the present invention. Fig. 11c shows a time domain rotor.

Fig. 12 shows a characteristic down-up-down signature structure used in accordance with embodiments of the present invention to determine ~~synchronisation~~ synchronization.

Figs.13a and 13b show the results of a sliding correlation on the LTS portion of a preamble when there is a CFO, Fig.13a shows the amplitude signal and Fig.13b the phase signal.--

Please replace lines 26-28 on page 8 as shown below:

--Figs.17a, 17b, 17c show various cross-correlation strategies in accordance with embodiments of the present invention.

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

Figs. 18a, 18b, 18c show the results of cross-correlation with the strategies of Fig. 17.--

Please amend the paragraphs beginning on page 9, line 7 through page 8, line13 as shown below:

--Figure 1 is a schematic representation of a non-limiting OFDM receiver 1. It comprises an antenna 2, a radio frequency receiver unit 3 usually comprising a filter, an analog to digital converter 4, a timing and frequency ~~synchronisation~~ synchronization unit 5 in which timing and frequency are extracted, a symbol timing is exported and the incoming signal is corrected for any frequency and/or timing offset, a unit 6 for removing the cyclic extension, a serial to parallel converter 7, a fast Fourier transform unit 8, a parallel to serial converter 9, a channel correction unit, 10, a QAM demapper 11, a deinterleaver 12 and a decoder 13. Such a receiver is known for instance from "OFDM for Wireless Multimedia Communications", Richard Van Nee and Ramjee Prasad, Artech House, 2000. The analog to digital converter is driven by a local controlled oscillator 14. The oscillator 14 can be controlled by the output of the ~~synchronisation~~ synchronization unit 5 to correct for any difference between the transmitter and receiver clocks.

The present invention relates, for instance, to a timing and frequency ~~synchronisation~~ synchronization unit which could be used in a receiver1. Generally, a transmitted signal contains a training sequence comprising at least a known succession of samples which the receiver can rely on. Usually, this is placed at the start of a frame although the present invention is not limited thereto, e. g. it includes mid-ambles or other positions of a training sequence. Also in the particular case of an OFDM frame, the preamble contains a cyclic prefix sequence.

One aspect of the present invention is to use a succession of at least two detection mechanisms in an optimized way, that is an autocorrelation (sliding correlation between two sets of received samples spaced in time) and a cross-correlation (correlation between expected or known samples and received samples). The sliding autocorrelation may be used to obtain a rough ~~synchronisation~~ synchronization timing, a characteristic relating to the carrier frequency offset and/or a rough value for the carrier frequency offset. Where the received signal has more than one training sequence (e. g. STS and LTS), the autocorrelation may be performed on more than one training sequence and different information may be obtained from the analysis of each

training sequence. The estimate of the carrier frequency offset may then be used to compensate the received signals for carrier frequency offset (CFO) before a more accurate estimate of timing is obtained by a cross-correlation between the received, compensated samples and the expected samples of a known training sequence. The known sequence used for cross- correlation is not necessarily the same as the sequence used for autocorrelation. For example, a sliding autocorrelation of one part of the preamble may be used to find initial information relating to the carrier frequency offset (e. g. the sign of the offset) and this initial information can be used to obtain a more accurate measure of the CFO by sliding autocorrelation of another part of the preamble. Using first of all the rough estimate and later the more accurate CFO value, a buffered input signal is compensated for CFO and then used to obtain a final accurate value of the symbol timing by cross-correlation with a known sequence.--

Please amend the paragraphs beginning on page 10, line 29 through page 11, line13 as shown below:

--Fig. 3 is a detail of a timing and frequency ~~synchronisation~~ synchronization unit 5 in accordance with an embodiment of the present invention. It comprises a buffer 15 for buffering received samples for a period of time until a first frequency offset value has been obtained in a frequency offset estimation unit 17. An autocorrelation unit 16 preferably outputs an autocorrelated amplitude and/or an autocorrelated phase signal of the received signal. The modules shown in Fig. 3 may map to real physical entities however there is no need for a one-to-one relationship with physical entities. For instance the complete system of Fig. 3 may be implemented in software running on a processing element such as a microprocessor.

In a first embodiment of the present invention, a first rough carrier frequency offset (CFO) is obtained by the frequency offset estimation unit 17 using an output of the autocorrelation unit 16. A first rough symbol timing is obtained by a ~~synchronisation~~ synchronization machine 20 using an output from the autocorrelation unit 16. At least the phase output (optionally the amplitude output as well) of the autocorrelation unit 16 is supplied to the frequency offset unit 17. The amplitude signal and/or the phase output from the autocorrelation unit 16 is supplied to the ~~synchronisation~~ synchronization machine 20. The CFO estimation unit

17 and the ~~synchronisation~~ synchronization machine 20 may both be parts of a processing engine based on a microprocessor.--

Please amend the paragraphs beginning on page 14, line 14 through page 16, line 9 as shown below:

--This correlation can be computed using the same autocorrelator unit 16 and frequency offset estimating unit 17 provided that the length and the distance of the correlation can be configured quickly after the STS samples are gone. A signal indicating that ~~synchronisation~~ synchronization has been obtained on the STS may be sent from the ~~synchronisation~~ synchronization machine 20 or if preferred from the CFO estimation unit 17. On receipt of the signal the units 16 and 17 change over to 32 sample correlation with D being 64 samples as described above. If the time is too short for reconfiguration, the units 16,17 may be duplicated and selected for the appropriate parts of the preamble as required. This reconfigurable infrastructure can also be used to track the cyclic prefix later on, during receipt of traffic data.

The following method of obtaining a rough timing may be used with either of the first and second embodiments. The amplitude output of Fig. 5e shows a section of about 120 samples when the correlation is high. This corresponds to the 9 B samples of the STS of the preamble of Fig. 2b. The inverse of B symbol(IB) causes loss of correlation followed by a short autocorrelation of the IB symbol. at sample 160. There are other features in the curve but these features are the most striking and can be used to identify this part of the sliding autocorrelation as being uniquely (or almost uniquely) related to the preamble. Hence, in accordance with an aspect of the present invention, features within the STS autocorrelation may be used to determine frame ~~synchronisation~~ synchronization. This frame ~~synchronisation~~ synchronization may be inaccurate but it is sufficient to determine a window within which frame ~~synchronisation~~ synchronization surely occurs, that is a time window in which the start of the frame is likely to occur. This window can then be used in other parts of the correlation to restrict the region of waveforms in the received signal which are examined. This reduces the risk of an erroneous match of waveforms and makes the ~~synchronisation~~ synchronization more robust. The width of

the window can be made configurable, e. g. the window is made larger if ~~synchronisation~~ synchronization is not achieved within a predetermined time.

In particular the characteristic of the steep drop followed by steep rise and then another steep drop between samples 144 and 174 can be used as distinctive feature of the amplitude curve. This form of curve can be ~~analysed~~ analyzed using a simple shift register circuit whereby the length of the shift register forms a sliding window which restricts the zone under analysis. This window can be restricted in such a way that the shift register is not much bigger than the distance across the down-up-down feature thus eliminating spurious additional features. Thus, in such an arrangement a low peak followed by a high peak is sought for, i.e., the values in the shift register must show this characteristic down-up-down feature. To identify the peaks and troughs local maxima and minima in the amplitude output may be detected. However, due to the effects of noise and the channel, the top portions of the peaks and the bottom portions of the troughs may be distorted. To avoid spurious ~~synchronisations~~ synchronizations threshold values may also be used to make sure that only very significant peaks and troughs are detected while not being misled by the exact form of the peak or the trough. An example of such upper and lower thresholds THI and TH2 is shown in Fig. 12. The present invention also includes adjusting the threshold values, e.g., THl and TH2, especially dynamically adjusting the values. A reason for adjusting the values may be to reach ~~synchronisation~~ synchronization faster. For example if ~~synchronisation~~ synchronization is not obtained within a reasonable time, e. g. within a first time, then the threshold values THI and TH2 may be adjusted so that they are further away from the peaks or nearer to the peaks shown in Fig. 12.

Thus, from knowing the expected curve it is possible to determine a rough timing of a specific symbol, e.g., of, IB at sample 160, with some security. The estimate of symbol timing is extracted in the ~~synchronisation~~ synchronization machine 20. In the case of the preamble of Fig. 2b, there is still a possibility that certain symbols in normal data traffic may mimic these structures. A similar analysis can be used to extract the same information from the phase diagram either instead of the amplitude detection or in addition thereto. The shape of curve of the phase output in Fig.5f, e.g., the180 jump, can be used by means for identifying this phase signature in the ~~synchronisation~~ synchronization machine 20 as a marker or signature to confirm

that the relevant part of the amplitude diagram of Fig. 5e does in fact relate to the training sequence being used for autocorrelation. This provides added security that the correct part of the autocorrelation output of unit 16 has been selected. In addition a third criterion can be used, e.g. the distance between the lower and following upper peak of Fig. 12 must be within a certain distance. A comparison between various criteria combinations is given the following table 1.--

Please amend the paragraphs beginning on page 16, line 13 through page 18, line 2 as shown below:

--In the first ~~synchronisation~~ synchronization algorithm only the phase jump in Fig. 5f is used to determine synchronisation. In the second algorithm, the presence of peaks above and below a certain threshold with the amplitude output of Figs. 5 a, c, e or g plus a distance between peaks within a tolerance and the phase jump within the phase outputs of Figs. 5b, d, f or h are used in combination to improve ~~synchronisation~~ synchronization. The values of the thresholds may be modified in accordance with a further aspect of the present invention to improve ~~synchronisation~~ synchronization. In the third case the detection of peaks (i.e., a local maximum or minimum) or relative thresholds is used in conjunction with the peak to peak distance within a tolerance and the phase jump. The relative thresholds may be adapted dynamically to improve ~~synchronisation~~ synchronization. The performance of the second and third ~~synchronisation~~ synchronization algorithms are better than using a single criterion such as the phase jump. In addition detection of the presence of plateaus may be used in either the amplitude and/or the phase outputs. In a preferred embodiment of the present invention a combination of conditions is used to determine rough ~~synchronisation~~ synchronization, e. g. at least two selected from an amplitude peak-maximum and/or minimum, an amplitude peak above and/or below a threshold, an amplitude peak-to-peak distance, the presence of a plateau in the phase or amplitude output and a phase jump, and preferably three of these criteria as indicated in the second and third algorithms in table 1.

Returning to Fig. 3, the output of the frequency offset unit 17 (independent of whether this is a fine or coarse estimate) is used by the frequency offset compensator 18 to correct the samples ready to be used for a subsequent cross-correlation with a known training sequence.

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

Cross-correlation is used to obtain an accurate timing. A cross- correlator unit may be as shown in Fig. 6 in the form of a matched filter. The sampling interval is given by T and Cl are the matched filter coefficients which are the complex conjugates of a known training sequence. The outputs from the filter stages are added in an adder 25. The output of the adder 25 is supplied to the ~~synchronisation~~ synchronization machine 20.

Fig. 7 shows the cross-correlation amplitude with sample number for the STS of the preamble shown in Fig. 2b. The curve shows various features (peaks) which are characteristic for the known training sequence. The form of the curve can be used to confirm that the correct part of the cross-correlation output has been used. From the correlation peaks an accurate symbol timing can be obtained. For example, the cross- correlation can be carried out on a selection of the nine B symbols and one IB symbol of the STS of Fig. 2b. For instance, a number of the B symbols and the IB symbol may be used, e. g. the last four symbols of the short training sequence can be used, that is B B B IB. In this case there are 64 taps on the filter. When this known sequence coincides with the same sequence in the received signal a high amplitude peak (100% correlation) is obtained. This appears at sample 160. To be relatively confident that the correct match has been obtained it is useful to look at other information-e. g. to check that the accurate timing is close to the rough timing obtained from autocorrelation. For example, it is advantageous to check whether the obtained timing is within the window determined by autocorrelation of the STS. The cross-correlation for other positions of the short training sequence is high but not so high for parts of the sequence where there are 3 B symbols common to the received signal and to the known sequence. This occurs at 6 symbol positions of the preamble. The other two positions have two B symbols common and one B symbol common. The first of these gives a still lower peak and the second of these gives a peak which is almost indistinguishable. Hence, by having means for identifying the characteristic peak sequence of, for example, 6 peaks at regular intervals followed by a peak at near 100% correlation, the ~~synchronisation~~ synchronization machine 20 can be relatively certain that the timing of the IB symbol has been obtained rather than a random correlation event. The ~~synchronisation~~ synchronization machine 20 can then output the accurate symbol timing.--

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

Please amend the paragraph beginning on page 20, line 27 through page 21, line 3 as shown below:

--The position of the window is provided by the information obtained with the autocorrelation, i.e., the end of the correlation plateau. The location of the window does not need to be accurate, the only requirement is that the peak is located within it. A longer window allows more margin for error. It is preferably not larger than the correlation distance, otherwise the window may contain at the same time both cross correlation amplitude peaks. The position of the peak within the window provides an accurate and precise synchronization reference. The detection of the peak can be done by finding the maximum and computing a relative threshold as described above for the ETSI preamble. The threshold values may be adjusted dynamically to improve ~~synchronisation~~ <u>synchronization</u>.--

Please amend the paragraphs beginning on page 21, line 23 through page 23, line 21 as shown below:

--Fig. 9a shows an overview of a ~~synchronisation~~ <u>synchronization</u> unit 20 in accordance with an embodiment of the present invention. It comprises a rough symbol timing circuit31, an accurate symbol timing circuit 32, a decision circuit 30. The output of the circuit is a timing reference indicative of ~~synchronisation~~ <u>synchronization</u>.

A rough symbol timing circuit 31 is shown schematically in Fig. 9b. Circuit 31 includes means to determine a symbol timing from an identified portion of the received signal and to output the symbol timing. It may also include means to determine whether a signature of a known training sequence correlates with the received signal. Either phase or amplitude outputs may be used, but the discussion below will be limited to amplitude. The amplitude signal from the correlation unit 16 is optionally fed in parallel to a buffer 34 and a comparator 36. The buffer 34 is configured to delay the signal by the length of the known training sequence. The optional comparator 36 compares the received signal with a stored signal from a memory 37 of the amplitude signature generated by the training sequence when processed in the autocorrelation unit 16 (e.g. a curve as shown in Fig.5e). The comparator 36 compares the two and outputs a

high logic signal when the correlation is high. This is fed to the rough symbol timing determination circuit 35 which may be configured as a peak and/or trough detector and determines a symbol timing from a predetermined position or positions in the signal under the assumption that it is processing a signature sequence, i.e., one correlated with the known sequence. The input from the circuit 36 is used to confirm that the ~~synchronisation~~ synchronization has been obtained and/or to reduce the window which has to be searched. Various techniques are known to the skilled person for determining ~~a~~ peaks and/or troughs. When it determines such a peak and/or trough it outputs a logic high signal to the decision circuit 30.

Fig. 9c is a schematic representation of an accurate symbol timing circuit 32. The circuit 32 includes means to determine from an identified portion of the received signal an accurate symbol timing. The circuit may optionally include means to determine whether a signature of a known training sequence correlates with the received signal. The amplitude output from the adder 25 of the cross-correlator unit 19 is the input to this circuit. The input is optionally fed in parallel to a buffer. 40 and a comparator 41. The buffer 40 delays the signal by one training sequence length. The optional comparator 41 compares the received signal with a signature of the amplitude signal from the known training sequence as output by the cross-correlator unit 19 (e. g. as in Fig. 7). The known signature is obtained from a memory 43. The comparator 41 compares the two and determines when correlation exists. The comparator 41 then sends a high logic signal to the accurate symbol timing determination circuit 42. The input from the comparator 41 is used to confirm that the ~~synchronisation~~ synchronization has been obtained and/or to reduce the window which has to be searched. Instead of using this signal the timing reference signal output from the ~~synchronisation~~ synchronization machine 20 could be used to identify where circuit 42 is to search. The circuit 42 may be configured as a peak detector and determines a symbol timing from a predetermined position in the signal under the assumption that it is processing a signature sequence. When it determines such a peak it outputs a logic high signal to the decision circuit 30.

The decision circuit 30 outputs a symbol timing signal based on the following logic. When there is only a signal from circuit 35 this is taken as the symbol timing, that is it is the

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

timing reference output. When there is a signal from both of the circuits 35 and 42 the decision circuit 30 can in one embodiment only select the signal from circuit 42 (assumed more accurate). In an alternative embodiment, the decision circuit compares the two signals from the circuits 35 and 42. If they differ by a threshold time value the decision circuit 30 assumes an error has occurred and outputs a reset signal which resets the process of rough and accurate ~~synchronisation~~ synchronization timing determination. If the time difference between the two signals is below the threshold it is assumed that no error has occurred and the timing signal from circuit 42 is output as the symbol timing.

After acquisition and ~~synchronisation~~ synchronization of the received signal, the correlation unit 16 mentioned above can be used but need not be used for tracking during the data stream and for determining clock offsets. This can be done by autocorrelation of the cyclic prefix of each symbol. However, this method is not accurate due to channel effects and intersymbol interference. Instead, in accordance with an embodiment of the present invention, the rotation of the constellation points in the received signal is determined in the frequency domain which is caused by the misalignment between the clocks of the transmitter and receiver. As shown in Fig. 3 a constellation point rotation unit 39 outputs a value related to the rotation of the constellation points in the received signal to the ~~synchronisation~~ synchronization machine 20. Referring to Fig. 9a, based on this value the decision circuit 30 outputs a signal for corrective action, e. g. one sample is skipped or duplicated in the time domain (received signal) if necessary.--

Please amend the paragraph beginning on page 24, line 30 through page 25, line 14 as shown below:

--The processor unit 51 comprises at least one microprocessor 52. The processor 52 first looks for a plateau in the amplitude signal coming from unit 44 (autocorrelated STS for all preambles of Fig. 2). The processor 52 searches for the end of the desired plateau. For example, for the preamble of Fig. 2b the processor 52 searches for a point where the distance between the positions of the minimum and the maximum in the sliding correlation shift register is in between redefined numbers dependent upon the relevant standard. Then, the processor 52 calculates a

Express Mail Label No. EV 292457545 US
Docket No.: S1022.81236US00
Mailed April 20, 2005

relative upper and a lower threshold using the maximum and the minimum values of the sliding correlation amplitude. These threshold values may be adapted dynamically to improve synchronisation ~~synchronisation~~ synchronization. Using these threshold values, it searches for the first sample where the sliding correlation amplitude is less than the upper threshold and at a previous point within the relevant distance, the correlation amplitude is greater than the lower threshold. The distance between these points is configurable by the processor 52. The peak of the correlation is the end of the STS. Now, the processor 52 checks for the phase jump of π (pi) between the current point and a previous point within a predefined distance in the phase signal from unit 44. The correlation phase is represented by two values having a phase offset in between, which is also configurable by the processor 52.--

Please amend the paragraphs beginning on page 25, line 32 through page

--The accurate symbol timing is obtained from the cross-correlation of the CFO compensated samples with a known training sequence available from unit 50. The processor searches for a particular waveform in this output depending upon the training sequence involved, e. g. searches for a large peak in this output. To ~~localise~~ localize this peak the rough ~~synchronisation~~ synchronization from the STS can be used to provide a window. The timing reference either rough or accurate is an output of the processor unit51. The cross- correlation can be done with a suitable known sequence, e. g. the STS or the LTS or both of the preambles of Fig. 2.

The above receiver may be configured to be a multimode receiver, i.e., it can receive and process any of the preambles of Fig. 2. To achieve this the processor 52 makes use of the configuration signals 53-56 to set the ~~synchronisation~~ synchronization unit to the appropriate algorithm.

The present invention also includes software computer programs which contain code which when executed on a processing means to carry out one or more of the methods of the invention. The ~~sofware~~ software may include code for processing a received signal comprising a carrier modulated with a known training sequence, comprising: code of obtaining an estimate of a carrier frequency offset from an autocorrelation signal obtained by autocorrelation of the part

of the received signal containing a known training sequence; code for compensating the received signal with the obtained estimate of the frequency offset to form a compensated received signal, and code for obtaining a timing reference for the received signal by cross-correlation of the compensated received signal with a known training sequence. The software code for the autocorrelation step may comprise code for detecting a characteristic curve in the amplitude of the autocorrelation signal indicative of a training sequence. The code for the autocorrelation step may also comprise code for detecting a characteristic curve in the phase of the autocorrelation signal indicative of the training sequence. The ~~sofwtare~~ software may also comprise code for determining a phase shift in the autocorrelation signal. The software may also comprise code for determining the carrier frequency offset from the phase shift. The software may also comprise code for determining a characteristic curve indicative of the training sequence in the amplitude of the cross-correlation of the compensated received signal with the known training sequence. The software may also comprise code for outputting the timing reference for the received signal obtained by autocorrelation of the received signal if the timing reference obtained by cross-correlation of the compensated received signal with the known training sequence is not present. The software may also comprise code for otherwise outputting the timing reference determined by cross-correlation of the compensated received signal with the known training sequence. The software may also comprise code for comparing the timing reference for the received signal obtained by cross-correlation of the compensated received signal with the known training sequence when present and the timing reference determined by autocorrelation of the received signal, and for outputting a reset signal if the two timing references differ by more than a threshold value and otherwise outputting the timing reference for the received signal obtained by cross- correlation of the compensated received signal with the known training sequence. The present invention also includes data carriers storing any of the above computer programs. The data carriers are preferably machine readable and execute a method according to the invention when loaded on a computing device. For example, the above software programs may be stored on any suitable data carrier such as CD-ROMs, diskettes, magnetic tape or may be included in the memory of a computer or of a network element.--

Please amend lines 22-27 on page 27 as shown below:

--The present invention may find advantageous use in receivers for telecommunications systems, especially for wireless communication systems and particularly for OFDM systems such as Local Area Networks (LAN). The present invention allows an accurate and robust ~~synchronisation~~ synchronization which is essential for operation at high bit rates and which can provide better bit error rate and improved quality of communication.

While the invention has been shown and described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes or modifications in form and detail may be made without departing from the scope and spirit of this invention.--

On page 27, line 32, please insert the following:

--What is claimed is:--